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MARINE FOULING RESEARCH, A STATE-OF-THE-ART REPORT

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U. S. NAVAL OCEANOGRAPHIC OFFICE
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ABSTRACT

This report is concerned with the present state of research on the ecology of marine fouling communities and the effects of fouling attachment on the performance of underwater equipment. An assessment is made of the amount and types of data in existence, the adequacy of these data, and the research methods involved in collecting and analyzing these data. An annotated listing of references is provided to show the extent and variety of fouling intelligence presently in existence and to provide a basic source of information directly related to practical fouling problems.

BACKGROUND

One of the most serious of the biological activities currently presenting problems to naval operations is the fouling and deterioration of submerged equipment and structures. Biological fouling is the assemblage of marine organisms that attaches to and grows upon underwater objects. The term fouling is generally limited to situations in which the results of the attachment may be considered harmful although there are recognized beneficial aspects as well.

Marine fouling is one of the oldest biological problems known to mariners and is the subject of written records dating to the fifth century B.C. (135). However, modern scientific investigation of sessile organisms did not begin until the mid-19th century when Edward Forbes and C. G. J. Peterson began designating marine biotopes by indigenous species of plants and animals. During this period, Kirchenpauer (62) performed what probably was the first comprehensive study of the fouling community when he compiled a list of 84 species from navigation buoys in the Elbe River. The use of test panels was introduced a short time later when Dahl (21) exposed wooden blocks in the Elbe to determine the time and rate of settling of fouling organisms.

FOULING EFFECTS

While the problems of fouling on ships' bottoms are well documented, the impairment of operation or the destruction of other kinds of military hardware by marine organisms only recently has been considered and is less well understood. Fouling will affect the hydrodynamic characteristics of sonar domes, resulting in an increase in water noise (24). Fouling is known to have an acoustic damping effect on underwater transducers, often reducing their sensitivity by as much as 10 db (36, 109, 119). Barham (6) reported that fouling on sound projectors and receivers will cause serious acoustic energy losses. More recently, oceanographic sensors have been affected by fouling organisms. Texas A and M University (107) noted that coelenterate fouling affected the movement of current meter rotors after 63 days of operation in the Gulf of Mexico. The U. S. Naval Oceanographic Office (112) found that after 120 days of unattended exposure in Penobscot Bay, Maine, electrical conductivity cells were desensitized by fouling organisms, resulting in salinity errors in excess of 4.0 parts per thousand.

Fouling has been shown to be damaging to protective coatings intended to reduce corrosion (37, 135). Some fouling organisms increase the corrosion rate of unprotected metal by the creation of oxygen concentration cells at points of adhesion. This has been shown to cause penetration of 1/16th inch stainless steel (tenelon) panels after only 111 days of marine exposure (125). The increase in acid metabolic products caused by dying members of the fouling community create a condition favorable to corrosion (106). Exposed moving parts may cease to function properly if appreciably fouled (116, 119), and it has been shown that moored mines will dip below

their intended depth after only 6 months because of the increase in resistance to water movement created by fouling growth (72, 110, 117).

While antifouling coatings adequately protect ships' hulls during the periods between drydockings, there are situations where this protection is entirely lacking or short term at best. Windows, sensor covers, moving parts, wire rope and cable, hydrofoil and other high speed surfaces (9), and conduits and water mains (98) are particularly difficult or impossible to protect effectively. A maintenance-free life of from 5 to 10 years required for underwater surveillance systems cannot be guaranteed by the present state of antifouling technology. A knowledge of the fouling community is required, therefore, for the proper design and maintenance of underwater installations.

FOULING RESEARCH ASSESSMENT

Extensive field studies have been performed and considerable information on the nature of the fouling community in various parts of the world has been published. These studies generally are fact-finding surveys at single locations to determine such fundamental information as seasonal succession, growth rates, and dominant organisms. These data are sometimes inadequate for the solution of practical fouling problems, however, because of the following serious shortcomings:

1. Insufficient areal coverage - The bulk of fouling investigations have been conducted in the temperate waters of the world. Data from tropical areas are less abundant and data from boreal areas are restricted almost exclusively to the Caspian and White Seas. Fouling data from deep water are almost non-existent; Dr. Sidney Galler of the Office of Naval Research has postulated, "the amount of data available on biological conditions in the ocean is inversely proportional to the depth of water".

2. Sites not representative - Fouling investigations traditionally are conducted off the ends of piers where the collected data often reflect local extremes of turbidity, pollution, temperature, and fresh water dilution. These harbor areas are not necessarily representative of the biological provinces in which they occur (Fig. 1).

3. Measurements not uniform - There has been no overall plan of research. For example, fouling data have been collected on wood, glass, slate, bakelite, concrete, steel, asbestos, plastics, and calcareous plates exposed vertically, horizontally, under rafts, or on permanent platforms. Experience has shown, however, that the tendency of different materials to foul is dependent on such variables as surface contour (20,73), texture and composition (7, 14, 91, 100, 132), color (124), and previous history (15). Fouling organisms also are influenced to attach by varying conditions of light (49, 71, 122, 126), water currents (18, 19, 32, 71, 102), gravity (53), stage of tide (38, 126), presence of other sessile organisms (22, 64, 80, 127), and angle of inclination of the surface (53,90). The collected data have been expressed as weight in water, wet weight in air, dry weight in air, alcohol wet weight, ash weight,

volumetric displacement, total volume, percent coverage, thickness, relative abundance, and combinations of the above. Critical evaluation is difficult when comparing investigations performed with different collectors or with non-standard techniques of exposure or analysis.

4. Investigations mostly short term - Most investigations have been carried out for only one season or one year, which may result in an atypical picture of the biological conditions for that locality. Coe and Allen (15), in summarizing 9 years of observations on the growth of sedentary organisms at a pier in LaJolla, California remarked that "each of the nine years has shown certain peculiarities both in the periodicity and in the abundance of some of the organisms found on the experimental blocks and plates." Loosanoff and Romejko (67) also noted that in 2 of 15 years studied, oyster set was as much as 40 times greater than in preceding years. Research must extend over a considerable number of years before normal or mean fouling conditions can be determined.

5. Environmental data lacking - Supplementary environmental data are lacking in some investigations. A meaningful fouling program should provide not only data concerning the composition, areal distribution, and seasonal accumulation of the biomass but observations of the chemical and physical environment as well. With the establishment of a productive basic ecological program in the various biological provinces, trends will appear in the occurrence and distribution of various foulers. As parallel trends in the environment become apparent, relationships can be postulated which will facilitate prediction of the type and degree of fouling in areas where no fouling data are available.

6. Qualitative information on the effects of fouling limited - Very little qualitative information is available on the effects of fouling and biological deterioration on sensors and other underwater equipment. A program to determine these effects is required in order to effectively relate fouling conditions to equipment performance.

FOULING COMMUNITY INDEX

An annotated listing of marine fouling community studies is provided in Appendix I. The term "marine fouling community studies" is defined here as one in which data, primarily concerned with the ecology of the fouling community, are obtained from test panels exposed at depths below mean low water. Presented in Appendix II is a representative selection of fouling investigations in which the ecology of the fouling community was of secondary concern or where surfaces other than test panels were employed. These appendices, plus the references in the text of this report, show the extent and variety of fouling community intelligence presently in existence and provide a basic source of information directly related to practical fouling problems. Not included are references to tidal zone investigations (which are concerned with a separate and distinct biotope) and basic studies of the biology and behavior of individual organisms (which are the subject of an extensive literature and beyond the scope of this report). Bibliographic information on these subjects is available in the Prevention of Deterioration Center bibliographies (92,93,94) and in "Marine Fouling and its Prevention" (135).

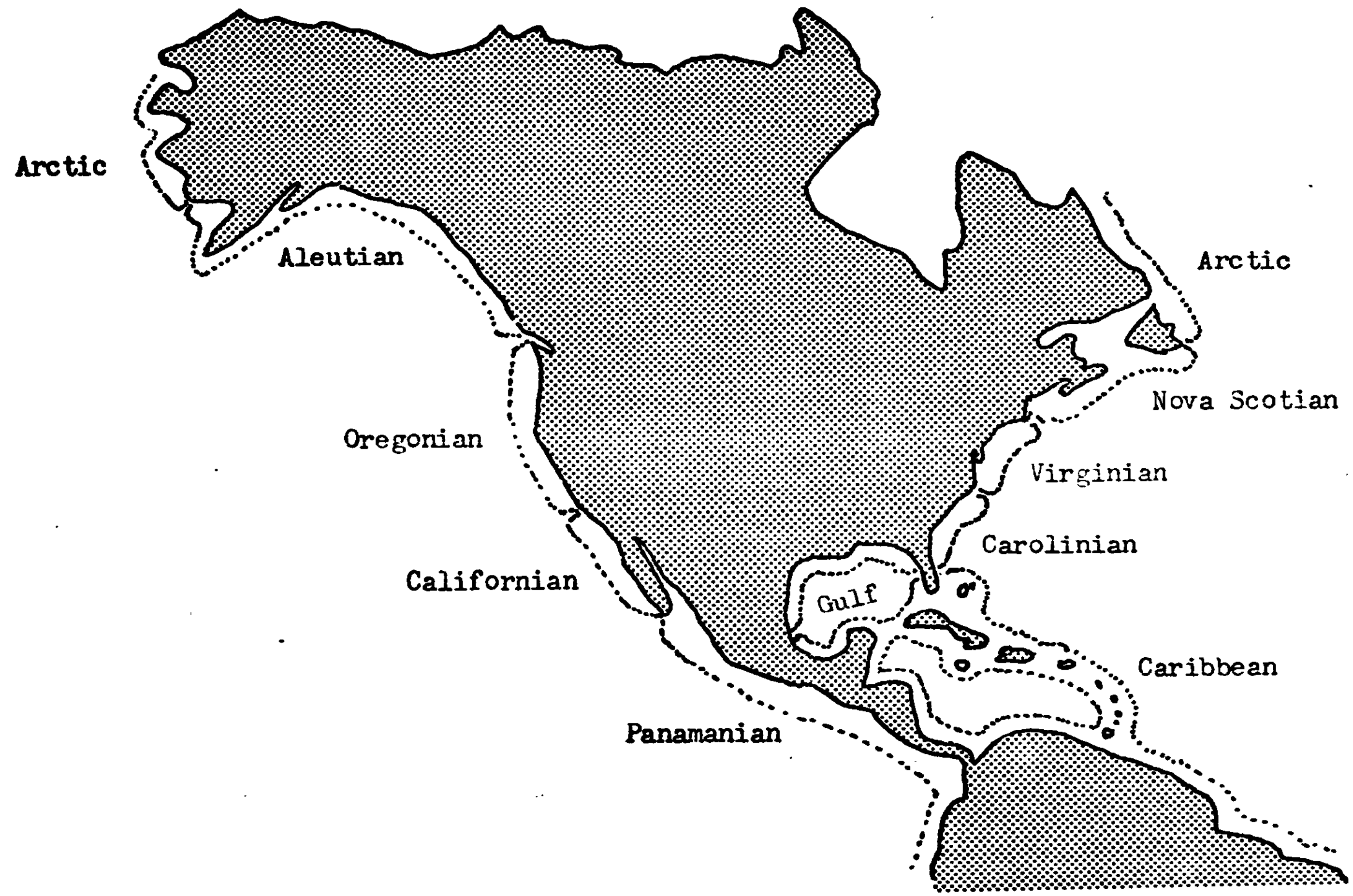

FIGURE 1 - MAJOR DIVISIONS OF THE COASTAL WATERS OF NORTH AND CENTRAL AMERICA
(Principally according to Valentine)

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Appendix I

MARINE FOULING COMMUNITY STUDIES

LOCALITY	REMARKS	REFERENCE #
Western Atlantic Ocean		
Argentia, Newfoundland	1964-continuing; wood-asbestos panels exposed offshore at depths of 50 to 140 feet for monthly and cumulative intervals up to one year; data expressed as numbers per panel per unit time, percent coverage, relative occurrence, dry weight in air, and rate of growth; temp and salinity data also collected.	114
Lamoine, Maine	Summer months 1943-44; weekly and cumulative shallow collections on asbestos panels exposed at pierside; data expressed as percent coverage, wet weight in air, dry weight in air, and numbers per panel per unit time; temp data also collected.	39
Rockland, Maine	1960-64; monthly and cumulative asbestos panels exposed offshore and pierside at several depths to 450 feet; data expressed as percent coverage, wet weight in air, dry weight in air, thickness, growth rate, and numbers per panel per unit time; temp, salinity, plankton, and transparency data also collected.	25
Duxbury, Mass.	1942-continuing; various materials exposed at pierside and beneath shallow rafts for monthly and cumulative periods; data expressed as percent coverage, relative abundance, and numbers per panel per unit time; temp and salinity data also collected.	95
Woods Hole, Mass.	Summer months 1922-32; short-term collections on glass slides, mollusk shells, stones, and bricks exposed at pierside; data expressed as numbers per panel per unit time, relative numbers, and rate of growth.	44

LOCALITY	REMARKS	REFERENCE #
Western Atlantic (Contd)		
Woods Hole, Mass.	1940-41; monthly collections on glass slides exposed at pierside; data expressed as numbers per square foot per month; temp data also collected.	61
Narragansett Bay	1955-57; monthly and cumulative collections on mine cases and glass test panels exposed at pierside and in shallow water to depths of 28 feet; data expressed as wet weight in air, displacement volumes, and relative numbers; temp, salinity, plankton, and bottom sediment data also collected.	81
Patuxent River, Md.	1962-64; monthly and cumulative pierside collections on wood-asbestos panels; data expressed as percent coverage, numbers per unit area per unit time, ash weight, organic carbon content, and relative occurrence; temp, salinity, nutrients, and oxygen data also collected.	17
Chesapeake Bay	1940-41; monthly collections on glass slides exposed at pierside; data expressed as numbers per square foot per month; temp data also collected.	61
Chesapeake Bay	1956-59; monthly and cumulative offshore collections (38 and 68 feet) on painted steel panels, metal stakes driven into the bottom; data expressed as numbers per square foot per unit time, wet weight in water, wet weight in air, dry weight in air, rate of growth, seasons of attachment, and relative occurrence; temp, salinity, transparency, and current data also collected.	23, 70
Chesapeake Bay	1941-42; monthly pierside collections on glass panels; data expressed as wet weight in air; temp data also collected.	129
Beaufort, N. C.	1940-41; monthly collections on glass slides exposed at pierside; data expressed as numbers per square foot per month; temp data also collected.	61

LOCALITY	REMARKS	REFERENCE #
Western Atlantic (Contd)		
Beaufort, N. C.	1941-42; monthly and cumulative collections made on wooden and glass panels and hearth tiles; data expressed as numbers per panel per unit time, growth rates, and relative occurrence; temp data also collected.	71
Wilmington, N. C.	1940-43; monthly cumulative pierside collections made on wooden panels; data expressed as numbers per square foot per month.	97
Daytona Beach, Fla.	1942; monthly and cumulative collections made on wooden panels exposed at pierside; data expressed as numbers per square foot per unit time.	96
Fort Lauderdale, Fla.	1962-continuing; monthly and cumulative offshore collections at depths from 50 to 300 feet on wood-asbestos panels, data expressed as numbers per panel per month, thickness, growth rate, percent coverage, dry weight in air, and relative occurrence; temp, salinity, and current data also collected.	29
Biscayne Bay, Fla.	1945-46; monthly and cumulative pierside collections on glass panels; data expressed as numbers per square foot per month, percent coverage, and growth rates; temp, salinity, oxygen, and plankton data also collected.	105
Biscayne Bay, Fla.	1943-47; monthly and cumulative shallow water collections on glass panels; data expressed as number per square foot per unit time and rate of growth; temp and salinity data also collected.	128

LOCALITY	REMARKS	REFERENCE #
Gulf of Mexico		
Pensacola, Fla.	1940-41; monthly collections on glass slides exposed at pierside; data expressed as numbers per square foot per month; temp data also collected.	61
Port Aransas, Tex.	1940; collections made on glass panels exposed beneath a barge for various periods of time; data expressed as numbers per square centimeter per unit time.	89
Eastern Pacific Ocean		
Balboa, Canal Zone	1957-59; steel panels exposed pierside and offshore at depths from 10 to 50 feet for monthly and cumulative periods up to one year; data expressed as numbers per panel per unit time, percent coverage, thickness, wet weight in air, dry weight, relative occurrence, and growth rates; temp, salinity, and bottom sediment data also collected.	26
San Diego, Calif.	1939-43; concrete blocks exposed for one month periods at pierside; data expressed as numbers per square foot per month and wet weights in air;temp data also collected.	130, 131
LaJolla, Calif.	1928-32; wood and concrete panels exposed for varying lengths of time at pierside; data expressed as numbers per square foot per month, relative occurrence, and growth rates; temp data also collected.	14
LaJolla, Calif.	1926-35; glass and concrete panels exposed bimonthly and cumulative at pierside; data expressed as total volume; temp data also collected.	15
La Jolla, Calif.	1956; wood, plexiglas, vinyl, glass, brass, zinc, stainless steel, copper exposed for three months at a depth of 45 feet; data expressed as numbers per panel.	1

LOCALITY	REMARKS	REFERENCE #
Eastern Pacific Ocean		
San Francisco, Calif.	1934-45; monthly collections on concrete blocks exposed at pierside; data expressed as wet weights in air; temp and salinity data also collected.	111
Oakland, Calif.	1940-42; monthly and cumulative wooden panels exposed beneath a bridge; data expressed as numbers per square foot per unit time, total volume, rates of growth; temp and salinity data also collected.	43
Friday Harbor, Wash.	1928-30; monthly and cumulative wooden panels exposed at shallow sites; data expressed as relative abundance and seasonal occurrence.	60
Admiralty Inlet, Wash.	1963-continuing; monthly and cumulative wood-asbestos panels exposed offshore at various depths, 50 to 300 feet; data expressed as numbers per square foot per month, dry weight, percent coverage, and rates of growth; temp and salinity data also collected.	113
Caribbean Sea		
Kingston, Jamaica	1960; various plastic materials exposed beneath rafts for periods of two and three months; data expressed as percent coverage, relative occurrence, and numbers per square foot per unit time; temp data also collected.	41, 42
Guantanamo Bay, Cuba	1936-38; wooden panels exposed at pierside for one month periods; data expressed as alcohol wet weights, dry weights, and relative occurrence; temp data also collected.	68
San Juan, Puerto Rico	1964-continuing, wood-asbestos panels exposed offshore at depths to 140 feet for monthly and cumulative intervals up to one year; data expressed as numbers per panel per month, percent coverage, relative occurrence, dry weight, and rate of growth; temp and salinity data also collected.	114

LOCALITY	REMARKS	REFERENCE #
Mid-Pacific Ocean		
Oahu, Hawaii	1940-44; monthly and cumulative wood, glass, and various materials exposed at pierside; data expressed as numbers per panel per month, relative occurrence.	34, 35
Oahu, Hawaii	1935-36; wooden panels exposed at pierside for periods of one and two months; data expressed as wet and dry weights of individual foulers.	123
Western Pacific Ocean		
Cavite, Philippine Is.	1936-38; wooden panels exposed at pierside for one month intervals; data expressed as alcohol wet weights, dry weights, and relative occurrence; temp data also collected.	68
Japan, Korea, and the Pescadores Islands	1925-27; glass, steel, and wooden panels exposed at pierside and offshore to 45 feet for monthly and cumulative periods up to one year; data expressed as numbers per square foot per month and dry weights.	99
Japan	1935-36; calcareous plates used for monthly and cumulative pierside exposures; data expressed as numbers per panel per month and relative occurrence; temp data also collected.	77
Japan and Pescadores Islands	1934; glass plates used for monthly pierside exposures; data expressed as dry weights.	58
Aburatsubo Bay, Japan	1951; glass panels exposed daily and for cumulative periods at shallow locations; data expressed as growth rates and sequence of attachment; temp and salinity data collected.	52

LOCALITY	REMARKS	REFERENCE #
Western Pacific Ocean (contd)		
Inland Sea, Japan	1957-58; concrete panels exposed at protected, unprotected, and intermediate shallow locations for varying periods of time; data expressed as numbers per unit time and sequence of attachment.	57
Japan	May to November 1954; slate panels exposed in shallow water for short periods of time; data expressed as numbers per square centimeter per unit time and relative occurrence with variously oriented surfaces.	51
Indian Ocean		
Gulf of Mannar	1952; wooden blocks used for monthly and cumulative exposures beneath rafts; data expressed as total volume.	65
Visakhapatnam, India	1955; asbestos, glass, wood, and cement used for semi-weekly and cumulative pierside exposures; data expressed as numbers per panel per week, relative occurrence; temp and salinity data also collected.	40
Madras, India	1940; glass, wood, cement, and iron panels used for monthly and cumulative pierside exposures; data expressed as numbers per panel per month and relative occurrence; temp and rainfall data also collected.	87
Persian Gulf		
Mina al-Ahmadi, Kuwait	1950-53; bakelite panels used for monthly and cumulative exposures at pierside; data expressed as relative occurrence, percent coverage, and numbers per square inch per unit time; temp data also collected.	48

LOCALITY	REMARKS	REFERENCE
Mediterranean Sea		
Haifa, Israel	1955; steel panels used for monthly and cumulative exposures beneath rafts; data expressed as relative abundance and seasonal sequence.	63
Golfo di Palmas, Sardinia	1963-continuing; wood-plexiglas and asbestos panels exposed for periods of up to 6 months offshore, from surface to bottom at 180 feet; data expressed as numbers per panel per unit time, size, thickness, and relative occurrence; temp and salinity data also collected.	30
English Channel and Irish Sea		
Mersey Estuary, England	1946-47, flooring tiles and scallop shells used for monthly and cumulative pierside exposures; data expressed as numbers per square inch per month and seasonal settlement.	16
Millport and Caernarvon, England	1940; painted steel panels exposed for short periods at pierside; data expressed as numbers per square foot per unit time.	8
Norwegian and Barents Seas		
Western Norway	1961; wooden panels exposed for various intervals at shallow locations; data expressed as numbers per panel, time of settlement, and vertical zonation; temp data also collected.	5
Spitzbergen	June to August 1921; oyster shells exposed at pierside; data expressed as occurrence or lack of occurrence only.	85

LOCALITY	REMARKS	REFERENCE #
Ekaterininskaya Bay, Barents Sea	June to September 1934; concrete panels exposed at shallow locations for various short periods; data expressed as wet weight in air; temp data also collected.	136
Caspian Sea		
Various sites, Caspian Sea	Observations of occurrence and distribution of fouling organisms attached to ships, underwater structures, and glass panels exposed for varying periods of time during 1951-61.	101, 13
South Atlantic Ocean		
Table Bay Harbour, South Africa	1946-49; experimental plates exposed for short periods at shallow locations; data expressed as numbers per panel, rate of growth, and sequence of settlement.	74
South Pacific Ocean		
Lyttleton, Australia	1954-55; test panels exposed at shallow locations for long and short periods; data expressed as numbers per panel, rate of growth, and sequence of settlement.	102
Sydney, Australia	1947-57; bakelite and perspex panels used for monthly and cumulative exposures under rafts; data expressed as relative occurrence, numbers per panel per unit time; temp and salinity data also collected.	56
Sydney, Australia	1948; glass panels exposed for short periods at pierside; data expressed as numbers per panel per unit time and relative occurrence.	134

LOCALITY	REMARKS	REFERENCE
South Pacific Ocean (continued)		
Sydney, Australia	1947-57; bakelite and perspex panels used for monthly and cumulative exposures under rafts; data expressed as relative occurrence, numbers per panel per unit time; temp and salinity data also collected.	133
Deep-Sea Areas		
Atlantic Ocean	1961-continuing; wood-asbestos panels exposed for periods of 48 to 57 days at various depths to 5,500 meters; data expressed as relative occurrence with depth.	108
Atlantic Ocean - Bahama Islands	1961-continuing; wood-asbestos panels and various materials exposed for periods up to 111 days at various depths to 1700 meters; data expressed as relative occurrence with depth, size, and thickness.	27, 28
Pacific Ocean	1962-continuing; various materials exposed for 4 months on the bottom at 5,640 feet; data not yet reported.	46
Pacific Ocean	1962-continuing; panels exposed for extended periods of time at deep-sea test sites; data not yet reported.	11

APPENDIX II

SUPPLEMENTARY FOULING INVESTIGATIONS

LOCALITY	REMARKS	REFERENCE #
Western Atlantic Ocean		
Atlantic Coast U. S.	Pre-1928 studies of fouling attached to hulls of ships docked at various ports of U. S.; period of attachment and substrate preferences noted.	122
Duxbury, Mass.	1955-continuing; wood, slate, plastic, asbestos, and steel panels exposed at pierside and beneath shallow rafts for monthly and cumulative periods, studies conducted with antifouling paint and corrosion tests; data expressed as numbers per panel per month, percent coverage, and relative abundance; temp, salinity, and oxygen data also collected.	84
Woods Hole, Mass.	Fouling observed on metal panels exposed at pierside during summer months only; data expressed as occurrence; study in connection with corrosion tests.	86
Woods Hole, Mass. Narragansett Bay, New York Sound	1937-40; fouling observed on channel buoys exposed for various periods up to 17 months at depths of 30 to 234 feet; data expressed as weight, thickness, and relative occurrence.	4, 45,
Boston, Mass. New York, N. Y. Baltimore, Md.	Fouling observed on wooden panels exposed at pierside for monthly and cumulative marine borer studies; data expressed as relative occurrence of major groups.	78
Narragansett Bay	Fouling observed in conjunction with research directed toward sonic control of fouling; data expressed as occurrance of various species.	82
Chesapeake Bay	Fouling observed on caissons removed from local harbor area; data expressed as occurrence only.	3

LOCALITY	REMARKS	REFERENCE
Wrightsville Beach, N. C.	Fouling observed in conjunction with research toward thermal control of fouling; data expressed as occurrence of various species.	95
Wrightsville Beach, N. C.	See Duxbury, Mass. above (Appendix II).	84
Charleston, S. C.	Fouling observed on floating drydock removed from local harbor area; species and wet weight in air noted.	69
Biscayne Bay, Fla.	Fouling observed in conjunction with research directed toward electrical control of fouling; data expressed as occurrence of various species.	12
Biscayne Bay, Fla.	See Duxbury, Mass. above (Appendix II).	84
Greenland	Early 1900 observations of fouling on buoys.	88
Mid-Atlantic Ocean		
Bermuda	Studies of the effects of deep-sea environment on rubberized fabrics exposed at depths from 200 to 16,000 feet; data not yet reported.	103
Atlantic Ocean	Studies of the effects of deep-sea environment on General Electric Corporation array components at depths to 5,500 meters; data not yet reported.	10
Caribbean Sea		
Guantanamo Bay, Cuba	Fouling observed in relation to periodicity of attachment to metallic samples; data expressed as occurrence of major groups.	118

LOCALITY	REMARKS	REFERENCE
Caribbean Sea (contd)		
San Juan, Puerto Rico	Fouling observed on mine cases and cables exposed for periods up to 6 months offshore; data expressed as relative occurrence of major groups.	116, 1
Bahama Islands	Fouling observed on cable and hydrophone mounts exposed on the bottom at 5100 feet for 16 months; data expressed as occurrence of major groups with depth.	75
Gulf of Mexico		
Texas Coast	1948-49; fouling observed on steel legs of offshore oil drilling platforms in shallow water; data expressed as relative occurrence and zonation; legs were protected with varying amounts of paint, asphalt, antifouling coatings, and sacrificial anodes.	50
Eastern Pacific Ocean		
Balboa, Canal Zone	Fouling observed on metal panels in conjunction with corrosion tests; data expressed as occurrence of major groups.	2
San Diego, Calif.	See Duxbury, Mass. above (Appendix II).	84
Redondo Beach, Calif.	Fouling observed in conjunction with thermal control of fouling research; data expressed as occurrence or absence of fouling attachment.	13
San Clemente Island	Fouling observed on mine cases and cables exposed for various periods of time at offshore locations; data not yet reported.	33

LOCALITY	REMARKS	REFERENCE
Eastern Pacific Ocean (contd)		
San Francisco, Calif.	Fouling observed on wooden panels exposed at pierside for monthly and cumulative marine borer studies; data expressed as relative occurrence of major groups of fouling organisms.	78
Dutch Harbor, Alaska	Fouling observed in conjunction with corrosion studies; data expressed as occurrence of major groups and season of attachment.	119
Pacific Ocean	Studies of the effects of deep-sea environment on rubberized fabrics exposed on the bottom at 5,000 feet for periods of 6 months to 2 years; data not yet reported.	103
Eastern Atlantic Ocean		
English Channel	Fouling observed on a sunken ship recovered after 6 months on the bottom at 280 feet; data expressed as relative abundance.	47
English Channel	Fouling observed on submarine cable recovered after varying periods of time at 500 to 1200 feet between Falmouth, England and Lisbon, Portugal; data expressed as occurrence only.	59
Plymouth, England	Fouling observed on metal panels used as controls in antifouling paint studies at shallow locations; data expressed as occurrence, season of attachment, and numbers per square foot per unit time; temp data also collected.	54, 7
Tamar and Mersey Estuaries, England	1930-37; fouling observed on channel buoys exposed for various periods from 12 to 15 months in shallow water; data expressed as relative occurrence; salinity, tidal, and pollution data also collected.	38, 7

LOCALITY	REMARKS	REFERENCE
Eastern Atlantic Ocean (contd)		
Portsmouth, England; Trondeheim, Norway; Drobak, Norway; Cuxhaven, Germany; Der Helder, Netherlands; Ostend, Belgium; Cherbourg, France; La Pollice, France; Abidjan, Ivory Coast.	See Duxbury, Mass. above (Appendix II).	83, 84
Mediterranean Sea		
Casablanca, Morocco	Fouling observed on mines exposed for various lengths of time up to 2 years offshore at depths of 25 to 90 feet during 1942-45; data expressed as relative occurrence.	110, 1
Haifa, Israel; Rovinj, Yugoslavia; Genoa, Italy; Toulon, France; Marseille, France	See Duxbury, Mass. above (Appendix II)	83, 8
South Pacific Ocean		
Sydney, Australia; Aukland, New Zealand	See Duxbury, Mass. above (Appendix II).	84

LOCALITY	REMARKS	REFERENCE
Sea of Azov		
Various Sites, Sea of Azov	Pre-1961; studies of fouling attachment to ships hulls; data expressed as periods of attachment and wet weight in air; temp, salinity, and light penetration data also collected.	66
General		
160 sites in North and South America, the Caribbean Sea, the Mediterranean Sea, the Pacific Islands.	Fouling organisms reported on wooden panels exposed at pierside for monthly and cumulative marine borer studies; data expressed as relative occurrence of major groups (occasionally to species) and percent coverage; occasional temp and salinity data also collected.	120